A ZOOGEOGRAPHIC SCHEME FOR THE MID-PACIFIC.

By Charles Hedley, F.L.S.

Three years ago it was my fortune to be attached as naturalist to the Royal Society Coral Boring Expedition, which operated on Funafuti, an atoll of the Ellice Group in the South Central Pacific. Previous to the arrival of this expedition the flora and fauna recorded in scientific literature from Funafuti amounted only to two plants, *Suriana maritima* and *Rhizophora mucronata*,* and seven snails, *Endodonta modicella*, *Stenogyra gracilis*, *Vertigo pediculus*, *Tornatellina conica*, *Truncatella valida*, *Omphalotropis zebriolata* and *Assiminea nitida*.†

One of the results of the expedition has been to identify and record a fauna of nearly nine hundred species. Of these one-sixth were described as new to science. Classified by sub-kingdoms, this fauna is composed of 2 Mammals, 15 Birds, 5 Reptiles, 73 Fishes, 2 Enteropneusts, 87 Crustaceans, 27 Arachnids, 5 Myriopods, 42 Insects, 440 Molluscs, 1 Brachiopod, 28 Echinoderms, 5 Annelids, 12 Gephyrean worms, 16 Sponges, 8 Hydrozoa, 2 Scyphozoa and 120 Actinozoa.‡

No other island of the Central Pacific has yet been so fully surveyed from a zoological standpoint. Having gained so much fresh information, it seems a suitable opportunity to pause and reflect what light it may throw on the distribution of life in this region.

Controversy has long raged around the geology of coral atolls. The scanty information possessed by science on their history and

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* Botting Hemsley—Chall. Report. Botany i. Pt. iv. pp. 131, 237.

† Mousson—Journ. de Conch. xxi. 1873, p. 107.

‡ Hedley—The Atoll of Funafuti; Memoirs iii. Australian Museum, 1899, pp. 513-535.

structure has been repeatedly dissected, scrutinised and pieced together by two generations of geologists. Yet the result of their labours has been rather the production of conflicting explanations than the discovery of fundamental principles on which all might agree.

Although the zoologist might at least claim a co-heritage with his geological brother in the subject of a coral atoll, but small share has been taken by naturalists in the discussion. Yet the great questions of whether the atolls of the Central Pacific represent the vanishing mountain tops of a drowned Trans-Pacific Continent or whether they are newly emerged land, should present problems as pertinent to zoological as to geological inquiry. And a zoologist whose attention has been claimed by them should be able to provide from his special store of knowledge means for their solution which are not at the disposal of his co-workers.

On this line of inquiry it is proposed to examine the fauna of Funafuti, and incidentally that of the Central Pacific, and endeavour to ascertain whether it is a Continental or an Oceanic Island, when and whence its fauna was derived.

From the standpoint of Zoogeography all islands are divided into two classes: Continental Islands which have been at a more or less distant period united to a continent, and Oceanic Islands which have never been so united. The distinction between their respective fauna and flora, is that while the first received its population by normal methods of migration, while it was a part of, or at a short distance from, the mainland; the second received only such animals and plants as might cross actively by flight or swimming, or be borne passively across the intervening space by winds or waves. Since such transmission would be easy for a few, difficult for many and impossible for most, the fauna and flora of an Oceanic Island will bear to an appreciative eye the distinctive stamp of its selective origin.

This idea appears to present much difficulty. For instance it is concluded by one writer that, "There seems to be an argument in a circle as far as oceanic insular floras are concerned. First of

all, it is assumed that if the depth is over a certain amount—say 1,000 fathoms—former land connection was not possible; then comes the study of the flora and fauna of those islands which are thus situated, and those are then looked upon as characteristic of such islands—other islands have these characteristics—the conclusion is drawn that they also have never been connected with the land."*

The only safe mode of reasoning is to eliminate the factor of the depth of intervening seas, since we cannot count the amount of past possible upheaval or depression, and to rely on biological data alone. Lest the important distinction between what Baur so happily terms "harmonic" and "disharmonic" faunas, should escape attention, I venture to again express it thus.

Let an area of say ten square miles be selected in, for example, England; a census of its fauna will yield a certain total of mammals, frogs, birds, fish and so on. Let another such census be made of an equal area in the United States and in Australia. Now though the individual species would be different in each of the three resulting catalogues, yet a general harmony in the proportion of each group to the whole will prevail. On contrasting the totality of the Central Pacific fauna with such lists, the gaps at once make discord. For example, the loss of the mammals, snakes and amphibia, leaves the whole Phylum Chordata with scarcely a representative in the Central Pacific.

The deduction from this comparison is that the population of the Central Pacific has been received by drift, from a continent or continental islands. Consequently all that the atolls have, their source should have also. But of the population of that source, only such may extend to the atolls as may first endure the ordeal of transit, and secondly obtain the means of life upon arrival. And the disharmony will result in the elimination from that atoll fauna, as compared to the continental, of the animals which have failed to comply with these two conditions.

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* Deane—Proc. Linn. Soc. N.S.W. xxi. 1896, p. 847.

The Continental Faunas.

Before we can profitably discuss the insular region of the mid-Pacific, we must grasp the main features of the continental area which lies to the west of it.

Broadly, the physical features of the latter are as follows:—The eastern coast of Australia presents a great and pretty uniform curve. An arc, which though diverging as it trends southward, somewhat corresponds to that curve, appears in broken segments in south-east New Guinea, the Louisiades, New Caledonia and New Zealand.* Beyond that again an outermost arc is formed by the Solomons and Fiji.

In the Central Pacific the curves are reversed. Towards Australia is presented the convexity of a long chain of archipelagoes which runs from the Marshalls, through the Gilberts, Ellice, Samoa and the Hervey to the Austral Islands, and which, as my reviewer in *Nature* suggests, is "perhaps represented still further to the south-east by the great Patagonian platform that projects north-westwards from the coast of South America."† This chain I call the Marshall-Austral chain.

To understand the source of the fauna of Funafuti, it will be necessary to trace the relations of the various continental faunas which lie nearest.

A large proportion of the Marine Invertebrates of Funafuti can be followed westwards through New Guinea, the Malay Archipelago, the Andamans, Ceylon, and Mauritius to the Red Sea. This tract is generally known as the Indo-Pacific or Oriental Region. Some writers have divided this region by a line which, running between Bali and Lombok, is called "Wallace's Line," after its describer. This division has occasioned much dispute

* Koto has remarked how "New Zealand and New Caledonia conform to the outcurve of Eastern Australia." (Journ. Coll. Sci. Univ. Tokyo, xi. Pt. ii. 1899, p. 114).

† *Nature*, 7th July, 1898, p. 221.

between zoologists. Meyer and Wigglesworth quote the opinions of thirty-six writers upon it.*

This, however, need not concern us here, and we may commence on the westward our inquiries with New Guinea. The use of political boundaries has much confused the lines of zoogeographical demarcation. "The Australian Region," meaning the continent of Australia, together with the Islands of New Guinea and the West Pacific, is an especially misleading term, and has tended to obscure natural boundaries. Within Australasia are several regions, peopled by distinct and unrelated faunas. To a zoologist, Australasia is not an entity, and may with advantage be dismissed from his vocabulary. I am unable to recognise New Zealand and other West Pacific Archipelagoes as appanages of Australia.†

It is first necessary to understand the faunal regions of Australia. In 1894 I published a short sketch, showing that three distinct faunal elements were included in this continent.‡ This view was afterwards accepted and amplified by Spencer.§ The oldest of these three, named by Tate the Autochthonian and by Spencer the Eyrean, has its chief seat in the extreme south-west, but its influence is perceptible across the continent to the north-

* Meyer and Wigglesworth—The Birds of Celebes, i., 1897.

† The usual classification of New Zealand originated at a time when the fauna was little known, and being uncontradicted has grown into general acceptance without due examination. Swainson appears to have introduced the idea by dividing (A Treatise on the Geography and Classification of Animals, 1835, p. 117) "the Australian Province" into "three subordinate districts. The first may comprehend New Guinea and its adjacent islands; the second, Australia properly so called, with Van Dieman's Land and New Zealand; and the third, the numerous groups of smaller islands clustered in the great Pacific Ocean." Sclater wrote more cautiously in 1857 (Journ. Linn. Soc. Zool. ii. p. 136), "I should be inclined for the present not to separate New Zealand and the Pacific Islands generally from the Australian division."

‡ Hedley—Proc. Austr. Assoc. Adv. Sci. 1893 (1894), pp. 444-6.

§ Spencer—Rep. Horn Sci. Exped. i. 1896, pp. 171-198.

east of Queensland. This fauna is not concerned in the zoology of the Pacific.

The second oldest Australian element is that called by Tate the Euronotian, and by Spencer the Bassian. It is the most characteristic Australian element, and consists of a rich fauna of Antarctic origin, which entering by Tasmania, overran the whole continent, crossed Torres Straits into New Guinea, and reached its utmost eastern limit in the Solomons. Characteristic members of it are the marsupials, monotremes, cystignathous frogs, venomous snakes, and snails of the Order Macroogna.*

The third and youngest Australian element, which has been called by Spencer the Torresian, was first noted by myself in 1892, when describing the irruption of Papuan Mollusca into Queensland;† a description which has been without acknowledgment appropriated by A. H. Cooke.‡

Along the whole east coast of Queensland a strong colony of Papuan fauna and flora is established. Among plants the wild banana, pepper, orange, and mangosteen, rhododendron, ephiphytic orchids, and the palms, among mammals, the bats and mice; among birds, the cassowary and rifle birds; among reptiles, the *Rana* or true frog, the crocodile, and the tree snakes; among butterflies, the *Ornithoptera;* and among mollusca, the operculate snails and the genus *Papuina*, characterise this element. So much is this so, that in the heart of a great Queensland "scrub," a naturalist could hardly answer from his surroundings whether he were in New Guinea or Australia.

Among recent writers, Haddon has shown that the islands of Torres Straits are the denuded remnants of a former extension of the Cape York Peninsula.§ A slight elevation of less than ten fathoms would now serve to connect the opposite shores of the Straits, and it is evident that it was by this route that the Papuan

* Hedley—Proc. Roy. Soc. N.S.W. xxix. 1895 (1896), pp. 278-286.

† Hedley—Proc. Linn. Soc. N.S.W. (2) vi. 1891 (1892), p. 694.

‡ Cooke—Camb. Nat. Hist. ii., Mollusca, 1895, p. 322.

§ Haddon, Sollas and Cole—Trans. Roy. Irish Acad. xxx. 1894.

emigrants reached Australia. The same land-bridge sufficed to admit numerous Australian plants and animals, such as the *Eucalyptus*, marsupials, and venomous snakes into New Guinea.

A considerable amount of specific difference has arisen since the isolation of this Papuan colony, and indicates a corresponding age for the water barrier of Torres Straits. An earlier, possibly Eocene, connection across Torres Straits is postulated by Pilsbry to explain the distribution of certain snails.*

New Guinea is a centre whence seem to me to radiate several streams of migration. That which crosses Torres Straits and passes down the Queensland coast, has just been described. A second runs a briefer course; it travels along the south-east peninsula, peoples the Louisiades, and terminates with that Archipelago. Characteristic of this area are the giant *Pupinellæ*.

Another stream branches off in German territory, traverses in succession New Britain and New Ireland, crosses to the Solomons and runs along the axis of that Group. Then, much impoverished, it divides, sending one branch to Fiji and another along the chain of the New Hebrides. Again, with lessened force, the latter turns to reach New Caledonia. Weaker still, it continues its course, sends an offshoot to Lord Howe Island, and ultimately arrives at New Zealand.

Since writing the above, I find that the path here suggested for the fauna was long ago traced by Lesson for the flora. As the remarks of that able writer appear to have sunk into undeserved oblivion, and as they are not generally accessible to students, I give the following free translation of a passage of his article "Coup d'œil sur les iles Océaniennes et le grand Océan."†

After remarking that in the vegetation might be found a clue like the thread of Ariadne to guide the inquirer aright through the maze of the South Sea Islands, he continues :—"The Indian flora flourishes in all its magnificence under the equator; commencing with the Sunda Islands, we follow it through Malaysia. It appears richly developed in the eastern Moluccas and in New

* Pilsbry—Man. Conch. ix. 1894, p. 127.

† Lesson—Ann. Sci. Natur. v. 1825, pp. 179-181.

Guinea. Here we find numerous palms and cycads, with ferns whose trunks form stately columns. The forests are composed of tall trees such as the Gatip, of long arborescent lianas and of numerous forms of leguminous plants. Here the food trees of Pacific islanders, such as the breadfruit, the spondias plum, and the banana, are indigenous. Following this superb vegetation, we see it diminish in proportion as we advance towards Torres Straits. Only a certain number cross into Australia, of which some characteristic members are the Indian *Erythrina*, two bananas, the *Flagellaria indica*, &c. But if instead of turning from New Guinea at Torres Straits, we follow the chain of islands leading to Polynesia, namely, New Britain and New Ireland, we find this vegetation still in full development, and the areca palm, the sago palm, the tree-ferns and the *Drymirhiza* still inhabit the forest. The neighbourhood of Port Praslin in New Ireland is clad with *Pandanus*, *Barringtonia*, *Calophyllum* and *Casuarina indica*. But in proportion as we advance southward to the New Hebrides and New Caledonia, the Indian vegetation decreases. Still further south, the temperate zone brings a change of climate. Norfolk Island produces an *Araucaria*, like that on the East Australian coast, and the *Phormium* which is common to New Zealand and peculiar to these islands. New Zealand, though not very distant from Australia, in no respect shares the productions of that vast country, but one still remarks, and this is worthy of attention, the Indian genera of plants such as the olive, the pepper and a reniform fern which recurs at Mauritius."

A centre of distribution has been described for New Guinea; another such occurs in New Zealand.

It is now generally admitted that a former southern prolongation connected that Archipelago with the Antarctic Continent. Thence were derived a fauna and flora akin to that now inhabiting South America, of which the New Zealand *Fuchsia* is a well known and typical example. Among mollusca, we point to the Rhytididæ and *Placostylus*. Along the tortuous route by which the Malayan forms crept south to New Zealand from New Guinea,

there flowed a return current of Antarctic life, which though feebler in lower latitudes may be traced up to New Guinea.

It is to be noted that the Antarctic fauna which passed over New Zealand is quite distinct from, and probably far older than, that other Antarctic element, the Euronotian, which reached Australia through Tasmania.*

Returning to a closer examination of the Malayan or Oriental stock, it seems probable that in its passage through New Guinea it recruited an Australian company, of which the Cuscus is a significant example. The spread of this element as far as the Solomons is so recent as to be obvious, and has been generally recognised. Beyond this point the progress of Malayan life is less distinct, and has given rise to diverse views. The importance of the classification of the Fijian fauna, in connection with that of the Central Pacific, warrants an attentive consideration of its relations with western continental lands.

From geological data it is evident that the Fijian Group has undergone much recent upheaval; previous to which it certainly underwent great subsidence. Prior to that subsidence, it is generally admitted that the group stood at a level sufficiently high to unite such outlying islands as Kandavu to the principal masses of Vanua Levu and Viti Levu. Such a union is indicated by the close affinity of their land molluscan fauna, and some measure of its antiquity is afforded by the specific differentiation which has arisen between corresponding species which represent each the other in different islands, as the various *Trochomorpha* and *Placostylus* do.

The writer was the first to contend that this former elevation not only sufficed to amalgamate the separate islands, but to join the whole to the Solomon Group.†

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* A few representatives in the West Pacific of tropical South American forms like the Queensland plants *Omphalea* and *Bursera* (Bailey—Rep. Austr. Assoc. Adv. Sci. vi. 1895, p. 393) and the Fijian lizard, *Brachylophus*, possibly indicate a trans-Polar migration antecedent to either referred to above.

† Hedley—Proc. Linn. Soc. N.S.W. (2), vii. 1892, p. 339; *idem*, xxiii. 1898, p. 99.

If subsidence had continued to the extent of lowering the whole group beneath the sea and drowning the indigenous terrestrial fauna, it is necessary to note that though on emergence the land would have acquired by drift a new fauna, yet that fauna would be disharmonic, and though geologists might still count it as continental by reason of its position on a continental platform, biologists on the other hand would class it as oceanic from the nature of its fauna and flora.

As the result of a geological reconnaissance in Fiji, Prof. Sollas reckons this and the Hawaiian Group in the latter category, as clusters of volcanic cones which, like Stromboli and Vulcano, rise from the depths of the sea, thus opposing them to true continental islands like New Caledonia and New Zealand.*

Some proof will now be advanced that this latter is an untenable position, and that Fiji has relics of an ancient and strictly continental fauna. The first writer to touch on the question seems to have been A. A. Gould, who in 1851 remarked :—"But if we may draw evidence from the land shells, the Samoan and Friendly Islands are more intimately related to the Society Islands, though at a much greater distance, than to the Feejee Islands. . . . Indeed, judging from the land shells, the Feejees are more nearly allied to the islands to the westward, such as the New Hebrides, than to the Friendly Islands on the east, though so much nearer."†

In 1892, I urged that :—"Eastwards of Fiji, the molluscan fauna indicates the abrupt termination of the Melanesian Plateau. Between the Samoas and Fijis a sounding of 2,600 fathoms has been obtained. Significant of this is the absence of *Placostylus* from Savaii, Upolu, or Tutuila. The Samoan Islands appear as well fitted as the Fijian to nourish an extensive series of *Placostylus*. They are large, densely wooded, with a warm, moist, and equable climate. The distance from their western neighbours is

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* Sollas—Natural Science, xiv. 1899, p. 17.

† Gould—United States Expl. Exped. xii. 1851, Mollusca, p. xiv.

no greater than from the latter to the groups to the westward, and not to be compared to the spaces between New Caledonia and Lord Howe Island or New Zealand, which have proved no obstacle to the spread of the genus. Yet the Samoas possess a distinctive oceanic molluscan fauna comparable to that of Tahiti, while the molluscan fauna of the Fijis is as distinctly continental."* My scheme and nomenclature were abstracted without acknowledgment by the Rev. A. H. Cooke.†

The reptilian fauna at once bears evidence of continental rank, and of derivation from the Solomons. Boulenger has recorded three species of frogs from Fiji, one of which, *Cornufer dorsalis*, recurs in the Solomons. E. R. Waite has published the occurrence in Fiji of a blind snake, *Typhlops aluensis*, hitherto only known from the Solomons.‡

T. Steel has described two land planarians from Fiji, *Geoplana trifasciata* and *Rhynchodemus scriptus*.§ The genus *Geoplana* is regarded as especially characteristic of continental areas. The land molluscan genus *Pupina*, which also seems peculiar to the continental region, finds its eastern limit in Fiji.

The Coleoptera of Fiji impressed Fairmaire as of a continental character. He draws a contrast between them and those of the oceanic islands of Tahiti and Marquesas.‖ I am indebted to Mr. J. J. Fletcher for a reference to this interesting article.

Among marine animals I have drawn attention to *Nautilus*, which inhabits Fiji, as confined to the coasts of the continental area. It has not strayed beyond the borders of the Melanesian Plateau, within which temperature limits its southern range to the Isle of Pines.

Glancing at the flora, it may be noted that W. B. Hemsley has described a remarkable Sapotaceous genus, *Chelonespermum*, of

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* Hedley—Proc. Linn. Soc. N.S.W. (2), vi. 1892, p. 336.

† Cooke—Camb. Nat. Hist. iii. 1895, p. 323.

‡ Waite—Proc. Linn. Soc. N.S.W. xxii. 1897, p. 685.

§ Steel—Proc. Linn. Soc. N.S.W. xxii. 1897, pp. 120-122, pl. vii., figs. 9, 10.

‖ L. Fairmaire—Ann. Soc. Ent. de France (6), ii. 1881, p. 241.

which two of the known species are from the Solomons, and the third from Fiji.*

Geological evidence may also be produced to substantiate the claim of Fiji to be called continental. Wichmann, whose work I quote at second hand from Baur, reports a considerable extension of old crystalline massive rocks and crystalline schists.† The latter include amphibolites, eurites, quartz-mica-schists and granular limestone. Among the older massive rocks occur granite, quartz porphyry,diorite, gabbro, diabase, foyaite, and a sandstone similar to itacolumit. Of minerals, gold, copper, quartz, pyrite, haematite and others were found.

Practically nothing is known of the fauna and flora of the Santa Cruz Group. I cannot therefore tell whether they should be classed as oceanic, or as their position at the intersection of the axes of the Solomons and the New Hebrides suggests, as continental.

The collection made by J. S. Gardiner on Rotuma, leaves no doubt of its oceanic nature.

Comparatively little biological research has been conducted in the New Hebrides. Enough, however, is known of them to constitute a link between the Solomons and New Caledonia.

A close relationship exists between the animals and plants of New Caledonia and New Zealand. That it has never been recognised by New Zealand writers, is simply owing to New Caledonian literature and material being inaccessible to them. The first to grasp the geological connection between the two countries was Heurteau.‡ A considerable correspondence occurs between the Mesozoic strata of each.§

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* Hemsley—Journ. Linn. Soc., Botany, xxx. 1894, p. 164.

† Wichmann—Ein Beitrag zur Petrographie des Viti-Archipels. Tschermak's Mineral. und Petrograph. Mittheilungen. (Neue Folge) v. 1883, pp. 1-60.

‡ Heurteau—Rapport sur la Constitution de la Nouvelle Calédonie, 1876, p. 17.

§ Pelatan—Les Mines de la Nouvelle Calédonie, 1892, pp. 14, 19.

In the recent fauna there is the same absence of all Mammals, except bats and rats, and the same poverty of Reptiles. Snakes are absent from both, and the Amphibia consist of one in New Zealand and none in New Caledonia.

Among the mollusca we note in each a close correspondence between *Melanopsis*, *Placostylus*, *Rhytida*, *Athoracophorus*, the *Charopa* group of *Endodonta*, and the *Rhytidopsis* and *Monomphalus* groups of *Flammulina*.*

The land mollusca of Lord Howe Island have a close affinity to those of New Caledonia.†

The foregoing account of the migration and classification of different faunas, usually confounded together as Australian, is diagrammatically represented in the accompanying map.

I beg to point out that this sketch is not constructed from contour levels and deep sea soundings. Ocean depths may yield to a zoogeographer valuable suggestions, and such have been here considered, but to follow them implicitly leads straight to error. The fact that *older movements may be less and younger more*, quite destroys the relevancy between present shallow water and former dry land. In these calculations the sea can be regarded as of one value only, that of a barrier to migration. The difference between a sea fifty fathoms and another five thousand fathoms deep may be that the former is of less duration than the latter. But unless biological data can be educed to support the youth of the smaller depth, it is for the zoologist of equal value to the greater. Thus the Arafura Sea though shallow separates more diverse faunas in Western Australia and Dutch New Guinea than does the deeper water which intervenes between Fiji and the Solomons.

The land mollusca have served me as a basis in the construction of this scheme.

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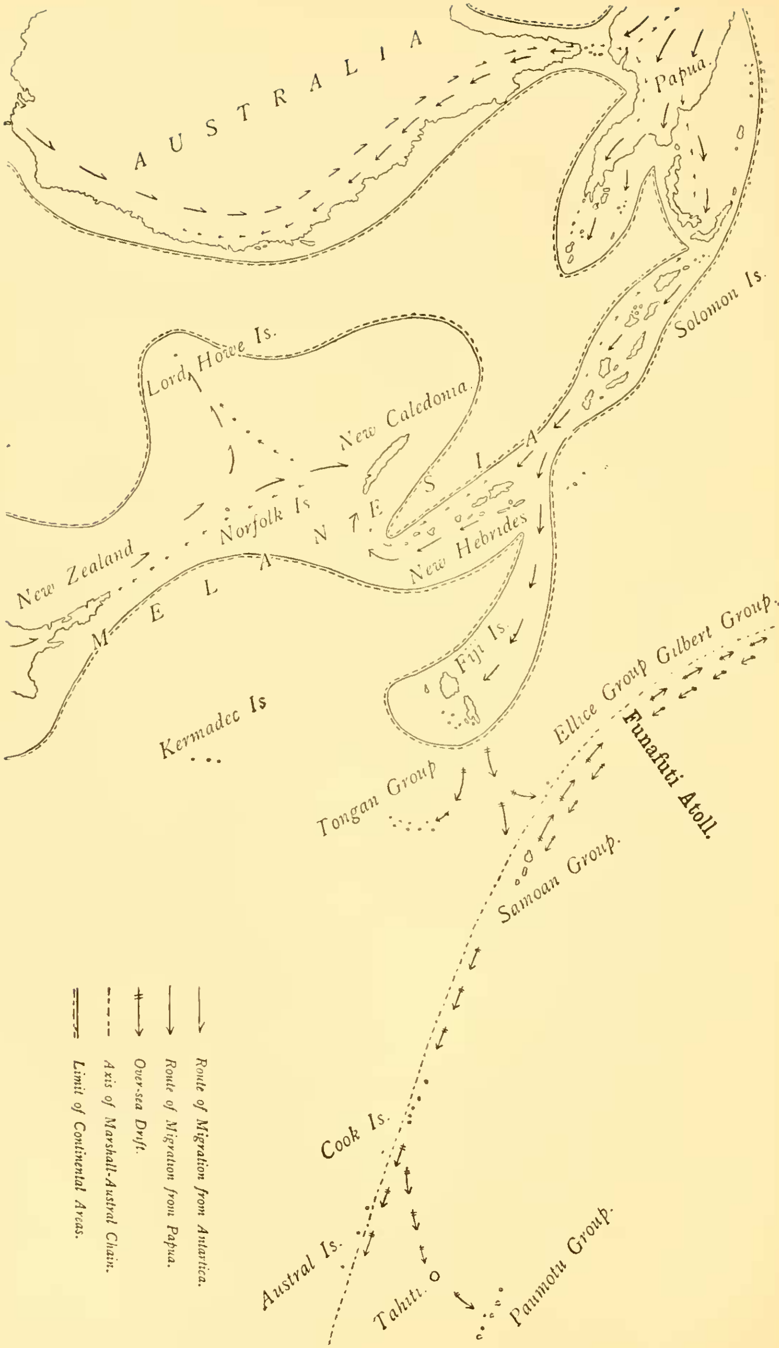
* Crosse—Journ. de Conch. xlii. 1894, p. 453.

† Hedley—Records Aust. Mus. i. 1891, pp. 134-144.


AUSTRALIA
Papua.
Solomon Is.
Lord Howe Is.
New Caledonia.
MELANESIA
Norfolk Is
New Zealand
New Hebrides
Fiji Is.
Kermadec Is
Tongan Group
Ellice Group
Gilbert Group.
Funafuti Atoll.
Samoan Group.
Cook Is.
Austral Is.
Tahiti.
Paumotu Group.
Route of Migration from Antartica.
Route of Migration from Papua.
Over-sea Drift.
Axis of Marshall-Austral Chain.
Limit of Continental Areas.

If this arrangement is a natural one, it will be found equally applicable to the remainder of the fauna and flora. For I have no sympathy with writers who plot out different areas for different groups of animals and plants with a view to the reconstruction of past continental land. Where the evidence of one group conflicts with that of another, either the testimony or the application is at fault.

The Route of the Polynesian Fauna.

Dr. Guppy* has suggested that Polynesia was peopled from the Malay Archipelago by two routes, the one by Micronesia and the other by Melanesia. In the first case, plants and animals may be traced from the Moluccas or the Philippines through the Pelews and Carolines to the Marshalls, and thence down a long chain of archipelagoes, including the Ellice, to the Austral and Paumotu Groups. By this route probably came the Pacific rat. In the second case Fiji formed the point of departure, and the invaders passed into Polynesia through Samoa.

A return current appears to have carried Melanesian forms back to the Carolines, Ladrones and Pelews. Evidence of this is given by the occurrence there of *Partula*, a genus which, as it evidently descended from the *Placostylus* stem, undoubtedly arose in Melanesia.

As the process of populating the Central Pacific Islands by drift from Melanesia is now in progress, it is almost superfluous to remark that both the Papuan and the Antarctic elements of the Melanesian Plateau have contributed to the Polynesian land Mollusca; the former giving *Tornatellina*, *Helicina* and *Trochomorpha*, and the latter *Partula* and *Endodonta*.

The route of the Polynesia fauna after its departure from the continent is too erratic to be exactly recovered.

Some useful data have been collected by Garrett, who tabulated the range of three families of marine Mollusca through ten archipelagoes of the Pacific, as follows†:—

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* Guppy—Trans. Vict. Inst. 1896.

† Garrett—Journ. Conch. i. 1878, p. 356, ii. 1879, p. 108, iii. 1880, p. 8.

	Conidæ.	Cypræidæ.	Mitridæ.
Fiji	60	44	117
Tonga	30	36	46
Samoa	41	41	73
Gilberts	44	43	42
Carolines	34	32	36
Cooks	34	36	41
Society	42	45	64
Paumotus	38	43	75
Marquesas...	14	13	6
Hawaii	21	31	31

An examination of these data shows a deterioration of the fauna from west to east, the five western archipelagoes mustering nearly one-fifth more than the eastern. The even distribution of *Cypræa* forms an exceptional case: it actually totals one species more in the Society Islands than it does in Fiji. With the exception of *Cypræa* there is a sharp fall in numbers on leaving the continental area of Fiji. From the nearest to the farthest groups the loss then continues in a parabolic curve. The most distant, the Marquesas and Hawaii, being in every case the poorest.

The Society Islands, however, possess a richer fauna than their distance appears to entitle them to have. This comparative wealth may be accounted for by their superior antiquity. The elevated masses of Tahiti and associated islands have for long stood in the drift track and intercepted migrant forms. It may even be that Tahiti has been receiving such from a time which anteceded the present form and population of the Melanesian area. A highly curious Tahitian tree, *Lepinia*, was lately rediscovered in the Solomons.* A subgenus of land shells, *Libera*, is peculiar to the Cook and Society Islands. They also possess half the known species of *Partula*.† Their poverty of insects as compared to western continental islands greatly impressed D'Urville.‡

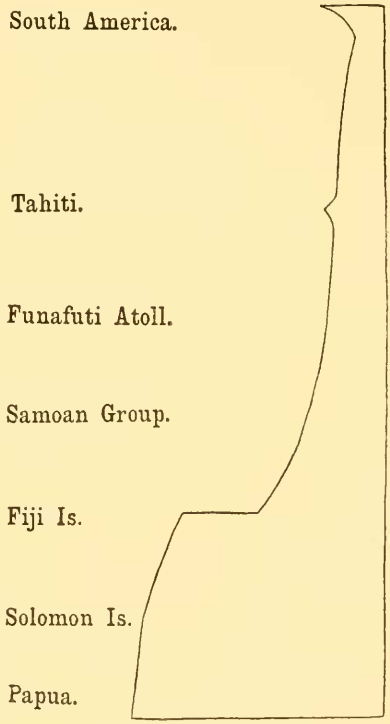
* Botting Hemsley—Science Progress, i. 1894, p. 30.

† Hartman—Bull. Mus. Comp. Zool. ix. 1881, p. 173.

‡ D'Urville in Boisduval—Voy. Astrolabe, Entomologie, i. 1832, pp. 20-22.

The average of Garrett's tables may be taken to roughly express the distribution of the fauna of this region generally.

This I would show diagrammatically by the descending line in the following figure:



From New Guinea as a starting point on the east the fauna declines slightly to Fiji. Leaving here the continental area, an abrupt fall occurs indicative of numerous feeble swimmers unable to cross deep water. Then through the nearer oceanic islands of Samoa, the fauna is by degrees sifted into strong and stronger swimmers. A small and sudden elevation occurs at Tahiti, and relates to the antiquity of that refuge for ocean waifs. Past Tahiti the life line slowly lowers till a minimum is reached at the point of furthest western intrusion of American life.

Though zoologists seem undecided on the question, botanists appear to be resolved that the flora of the Central Pacific Archipelagoes reached them as over sea drift. W. B. Hemsley writes: "For the purposes of the 'Botany' of the Challenger Expedition and ever since the publication of that work, I have collected all the data coming under my notice bearing on the dispersal of plants to considerable distances by wind, water, birds or other creatures

excepting human. The evidence thus collected sufficiently accounts for the vegetation of low coral islands."*

Though I have not data to prove the suggestion, I venture to submit that seaweeds have slight extension in the Central Pacific. I was struck by their comparative absence on Funafuti. Kotzebue observes—"Algæ, which seem to be entirely wanting on the low islands, are found on the reefs at the foot of the high land."†

The only terrestrial mammal with any claim to be regarded as native to the Central Pacific is the Rat, *Mus exulans*. But Thomas‡ considers that "it has probably travelled from island to island in native canoes or on floating logs, etc., long before European ships began to bring over the ubiquitous Grey and Black Rat." Confirmation that such was the case is supplied by Kotzebue, who mentions the opinion of a well informed Marshall islander, "Kadu, who seems to think that the rat is only to be found in the company of man, affirms that there are none on Bygar."§

No Bats have reached the Ellice Group. The eastern limit of the Dugong does not seem to be definitely known. The farthest record I have is New Caledonia.‖ It certainly does not attain the Central Pacific, and I apprehend that it does not stray beyond the continental area in the southern hemisphere, though in the northern I believe that it reaches the Pelews.¶ This latter group seems to be a continental outpost in the Northern Pacific, corresponding to Fiji in the Southern.

There is an interesting record of a stray seal having once reached Polynesia. Dr. W. Wyatt Gill wrote: "A native of Mangaia one day came running to me saying that Satan had just

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* Hemsley—Nature, lii. 1895, p. 623.

† Kotzebue—A Voyage of Discovery into the South Sea and Beerings Straits, iii. 1821, p. 144.

‡ Thomas—P.Z.S. 1895, p. 338.

§ Kotzebue, *loc. cit.* p. 156.

‖ J. Garnier—Voyage autour du Monde, 1871, p. 182.

¶ Kotzebue, *op. cit.* iii. p. 191.

landed on the northern coast of the island. . . . But another native fishing on the reef, who had some experience in the Arctic regions, happened also to see this marine animal, and recognised it as a fur seal."*

The terrestrial reptilian fauna is represented on Funafuti by four Lacertilians. Of one of them, Dr. Baur remarks—"The next species, *Gehyra oceanica*, Lesson, reaches from the Moluccas eastwards to the Cook Islands (Rarotonga), being found on the Admiralty, Solomon, Fiji, Tonga and Samoa Islands, Savage Island and Lord Howe Island. . . . This distribution can only be explained by a former Indo-Pacific continent extending from Malaysia to the west coast of America."† A little local knowledge of the region on which he wrote might have saved Baur from drawing so tremendous a deduction from so simple a fact. Observation on the spot enables C. M. Woodford‡ to thus easily explain the matter, without invoking a Jurassic Continent. "It is the rule rather than the exception for one or more lizards to be unwilling passengers when one of the large native canoes is at any time put into the water . . . their presence therefore, even upon remote islands, presents little difficulty."

The Green Turtle occurs at Funafuti, and may, I believe, be traced to the uttermost limits of Polynesia. Other members of this group of powerful swimmers are widely spread in the South Seas. Gill says—"Several species of Turtle—Loggerhead, Hawksbill, Green Turtle, etc.—are very plentiful on Rakaanga in the breeding season."§

Crocodiles do not, to my knowledge, intrude further into the South Pacific than the Solomons, though their appearance in the Santa Cruz and New Hebrides would not be surprising. The ascription of them to Fiji by Boulenger‖ is contradicted by local observers. Mariner has given a vivid account of a stray crocodile

* Gill—Jottings from the Pacific, 1885, p. 125.

† Baur, *loc. cit.* p. 880.

‡ Woodford—Geogr. Journal, vi. 1895, p. 349.

§ Gill—Jottings from the Pacific, 1885, p. 128.

‖ Boulenger—Cat. Chelonians and Crocodiles, Brit. Mus. 1889, p. 285

which once reached Fiji, and was killed by the natives. "It was the first animal of the kind the natives had ever seen or heard of."*

It is probable that both the land birds and the Lepidoptera were blown to the Ellice Group. From facts which he advances, especially their absence from Fiji and the Solomons, Woodford concludes† that *Remigia translata*, *Cephonodes hylas*, and *Chloanges suralis* reached the Gilberts from Eastern Asia by way of the Marshall Group. When we add that they passed on from the Gilberts to the Ellice, we but take another step along the same path. It is noteworthy how the thoughts of two such excellent naturalists as Guppy and Woodford, who gained their knowledge of the Pacific on the spot, independently agree in tracing the same path of migration for plants and insects respectively. Were we in doubt as to the last step between the Gilberts and Ellice taken by migrating butterflies, it should be removed by Kotzebue, who when precisely midway between the two archipelagoes wrote —"When we were exactly in 4° 15′ latitude and 178° longitude, heavy gales brought swarms of butterflies and small land-birds to the ship; we must therefore have been near land, but we looked for it in vain; and this discovery remains for some future navigator."‡

The birds blown from atoll to atoll in the way the foregoing passage describes, would be themselves the unconscious vehicle of small animals or plants. J. J. Lister writes—"At Canton Island a clump of *Tournefortia* trees was habitually used by these birds *(Sula piscatrix)* as a roosting and preening place. Among the pieces of down which were sticking to the bare branches having been preened out of the feathers, was found one entangled with a seed of one of the trailing plants of the island *(Boerhavia tetrandra*, Forster), which is beset with glandular hairs. Such an

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* Mariner—Tonga Islands, i. 1817, p. 337.

† Woodford, *loc. cit.*

‡ Kotzebue—A New Voyage Round the World, i. 1830, p. 292.

incident indicates a method by which seeds may be distributed from island to island by birds."*

Attention may be profitably given to an efficient agent in distribution, which though not entirely unnoticed,† has excited little remark. Every one who has crossed a woodland tract in windy weather has seen handfuls of dead leaves whirled up by eddying gusts. Let such a gust pick up such leaves from a Pacific atoll, during the height of a violent cyclone, they travel softly, without jarring off what has adhered to them, and may easily be dropt on an atoll a hundred miles distant after a few hours. To all collectors it is well known what numbers of small Invertebrates attach, either as ova, larva or adult, to fallen leaves. So a shower of a few dead leaves might throw at once a dozen species of insects, spiders and snails on an island where no life was before. I am satisfied that herein lies the explanation of the wide distribution of *Helicina*, *Endodonta* and *Tornatellina* in the South Pacific.

The introduction of fleas and mosquitoes to the islands of the eastern Pacific is a matter of recent history. Dr. W. W. Gill has stated that mosquitoes were accidentally conveyed in water casks to Penrhyn and Rakaanga in 1859, and to Manihiki in 1862.‡

Dr. Baur lays great stress on the fact that ants are represented by numerous species and genera in the Mid-Pacific. I am, however, unable to follow him in deducing therefrom that "it is quite evident that this distribution of the Formicidæ cannot be explained by accidental introduction. Also here we are forced to accept a former Pacific continent."§ He apparently overlooked the fact that at one period of their lives both sexes of ants are endowed with considerable powers of flight, and might then be blown from one island to another.

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* Lister—Proc. Zool. Soc. ii. 3, 1891, p. 294.

† Kew—The Dispersal of Shells, 1893, p. 146.

‡ Gill—Jottings from the Pacific, 1885, p. 162.

§ Baur—American Naturalist, xxxi. 1897, p. 878.

Dr. Baur in continuation of his argument has pointed out that "*Pocillopora*, a coral of the Madreporaria, is found only in the Indo-Pacific region. It is represented by an extraordinary large number of forms reaching north to the Loo Choo and Sandwich Islands, and is also common on the west coast of America. It is totally absent, however, from the Carribbean or West Indian Sea and the eastern American coral region. . . . The general distribution of *Pocillopora* and the Trapeziidæ in the Indo-Pacific region can only be explained by a former land connection of this region. . . . If we consider the Pacific Islands as the remains of a former Pacific Continent, we have no difficulty whatever in explaining the general distribution of *Pocillopora*."*

In this deduction Baur failed to remember Darwin's caution—"How ignorant we are with respect to the many curious means of occasional transport." Though it was hardly to be anticipated that the problem could be so neatly solved, we can demonstrate in the case of this identical genus how fallacious is the support which *Pocillopora* appears to give to the hypothetical former Pacific Continent.

Kent collected on Cairn Cross Beach, Barrier Reef, Queensland, "a rounded lump of pumice stone, about $3\frac{1}{2}$ inches in diameter, to which two young coralla of the madrepore, *Pocillopora damicornis*, were attached. The bases of the coralla are each about $1\frac{1}{2}$ inch wide, and the rudimentary tuberculate branchlets are about $\frac{3}{4}$ of an inch high. This specimen was thrown on the beach in a buoyant condition, as is evident by its still floating lightly even in fresh water. The attached *Pocillopora* probably represent the growth of a few months only, and would, at an early date, have completely invested the pumice stone fulcrum, and caused it to sink."†

The beaches of Eastern Australia are bestrewn with flotsam from the West Pacific Archipelagoes, including South Sea canoes,

* Baur, *loc. cit.* p. 864.

† Kent—The Great Barrier Reef of Australia, 1893, p. 122.

empty *Nautilus* shells, pumice, coco-nuts and fruits of *Barringtonia butonica*.* My colleague, Mr. T. Whitelegge, has shown me pieces of pumice which he collected on a beach near Sydney. To these adhered young coralla of *Pocillopora* similar to those observed by Kent in Queensland. The unique occurrence of a live *Pocillopora* on rocks near Sydney noted by Mr. Whitelegge may be thus explained.†

Guppy furnishes the following evidence from the Indian Ocean: "Washed up on the weather side of North Keeling Island I found a piece of Krakatoa pumice, on which had grown four bosses of a pretty incrusting species of *Pocillopora*, each of the size of a dollar and $\frac{1}{4}$ to $\frac{1}{2}$ inch in thickness. This piece of pumice still floated buoyantly, and had evidently been caught in the reef for some time before it had been thrown up on the beach. Mrs. Ross showed me specimens about three times the size, of the same species of *Pocillopora*, that had grown on a large log of timber, which having been caught in the outer edge of the reef for about a fortnight, had then been rolled on shore. . . . Mr. Ross subsequently informed me that not infrequently large blocks of corals, mostly of the massive astrean type, and foreign to the atoll, are washed ashore on the western coasts of the eastern islands. He showed me one in his possession, a massive astrean coral, which was six feet in circumference and weighed 88 lbs., and in order to convince me of its buoyancy he had it carried to the beach and thrown into the water, when it floated readily."‡

F. Jousseaume states that corals attach themselves even to the shells of turtles and the skins of marine animals.§

The Nereid worm "Palolo" extends from Torres Straits and the continental islands eastwards to Samoa and Tonga, but is unknown to the natives of the Ellice, the Gilberts or the

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* Hedley—Proc. Linn. Soc. N.S.W. xxiv. 1899, p. 192.

† Whitelegge—Proc. Roy. Soc. N.S.W. xxiii. 1889, p. 191.

‡ Guppy—Scot. Geograph. Mag. v. 1889, p. 288.

§ Jousseaume—La Philosophie aux prises avec la Mer Rouge, le Darwinisme et les trois Règnes des corps organisés, 1899, p. 241.

Marshalls.* A division of the Polynesian calendar is called Palolo, and in a philological connection Hale has drawn attention to the absence of this worm from eastern Polynesia.†

Among the marine molluscan fauna of most regions are certain genera which impress a geographical stamp upon the whole. Thus *Trigonia* in Australia, *Nautilus* in Melanesia, *Struthiolaria* in the circum-Antarctic zone, *Eburna* in East Asia and *Concholepas* in west South America, each express a key-note of their respective fauna. The Mollusca of Funafuti contain no such form. If spread out in a series on a table they would merely suggest to a conchologist that they came from tropical latitudes, between the longitudes of Mauritius and Hawaii, without affording him a clue to more exact locality.

Indeed, as in all oceanic islands, the absence of certain forms is more remarkable than the presence of others. Throughout the continental islands nearest to Funafuti—New Guinea, the Solomons and Fiji—various species of *Melo*, *Voluta* and *Nautilus* are abundant and conspicuous. The line which I draw between the oceanic and continental islands, is, however, an insuperable barrier to these, though it is none to such genera as *Mitra*, *Conus*, or *Cypraea*, which flourish within and beyond it. The reason suggested is that *the former lay eggs of great size, the young have no trochosphere stage and are already bulky when hatched.* They are not therefore capable of crossing spaces of open sea like the others.

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* Krämer—Biologisches Centralblatt, xix. 1899, p. 18.

† "Palolo in Samoan is the name of a kind of sea-worm which makes its appearance in shoals in the reefs, at a certain time of year, and is esteemed a great delicacy by the natives. This worm is not known at the Society Islands, but the name is still retained, with no meaning whatever attached to it—a striking evidence of the derivation of the Tahitians from Samoa."—(Hale, U.S. Expl. Exped. Ethnography and Philology, viii. 1846). This argument appears to me unsound. To cite a parallel case, would it not be considered rather that the English called the Hawthorn "May," from the month in which it flowered, than that the shrub gave its name to the month?

In tropical latitudes the family Onchidiidæ are usually numerous; their complete absence at Funafuti therefore struck me as remarkable. Samoa and Tonga appear to be their farthest stations in the West Pacific. Their limited powers of migration are explained by the statement of J. Joyeux-Laffuie that—"The whole development of *Onchidium* takes place within the egg, and the young at the time of hatching already possess the form of the adult."*

I should suppose indeed that the bulk of the molluscan fauna reached Funafuti in the larval swimming stage.

Fischer records† having taken in the open sea a *Triforis* which, although eight or nine whorls of the shell were formed, still retained the larval, *i.e.*, swimming characters. In the light of this statement the wide range which *Triforis* enjoys in Polynesia might have been anticipated.

Little is known of the comparative endurance of the swimming larval stages of Mollusca. That Pelecypoda range farther than Gasteropoda suggests that they swim longer. *Tritonium* and *Cerithium* should by their distribution be gifted with unusual swimming powers.

That the Polyplacophera should only be represented by a fragment in the roll of the Funafuti Mollusca is quite in keeping with the distribution of this order in the Central Pacific. But six species were known from this region to Harper Pease, who in his last paper wrote—"The absence of Chitonidæ from Polynesia has been noticed by authors as a remarkable fact, abounding as they do in the surrounding provinces, especially on the west coast of America, at Australia and New Zealand."‡

Interesting results would be reached by tabulating marine Invertebrata, according as they travel much, a little, or not at all, in the early stages of their development; by plotting the geographical distribution of each, and comparing the results.

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* Joyeux-Laffuie—Archives Zool. Expér. x. 1882, p. 353.

† Fischer—Manuel Conch., 1887, p. 679.

‡ Pease—Am. Journ. Conch. vii. 1872, p. 194.

Such data as I have suggest that the distribution obtained in the Eastern Pacific would be described by concentric zones of which the outer would be attained only by the strongest swimmers.

Mr. T. Whitelegge has pointed out to me that the Australian starfish, *Asterina exigua*, never passes through a free pelagic stage, but goes through all stages of development on the rock on which the egg is laid and to which it adheres. I cannot, however, divide the Echinodermata by similar and opposite habits, sufficiently to draw any conclusions from them.

The abundance of Crustacea at Funafuti agrees with their larval capacity of swimming. The same may be said of the occurrence there of Enteropneusta, Gephyrea and Actinozoa. The genera of Reef Corals diminish markedly in number from west to east. We noticed the absence from Funafuti of many genera usually common and conspicuous on continental islands, such as *Galaxea*.

Too few examples were obtained at Funafuti of the fauna of the deep sea to admit of much discussion. The interesting Palu, *Ruvettus pretiosus*, however, supports the opinion that a general uniformity prevails over vast areas, if not indeed all round the world, among abyssal animals.

Our increased knowledge develops distinctions more than affinities between the Central Pacific and tropical Atlantic. But the list of species either closely related in or common to both oceans has been lately enlarged, both among deep and shallow water forms. Willey has commented on the affinity between *Asymmetron caudatum* from the Louisiades, and *A. lucayanum* from the Bahamas.* Before its discovery at Funafuti, the sponge *Hippospongia dura* was only known from the Atlantic coast of North America. The fish *Ruvettus pretiosus* is now shown to be common to both oceans, and the new Brachiopod from Funafuti finds a close ally in *Thecidium barretti* from the West Indies. I have drawn attention to the relation of *Iphitus tuberculatus*, Watson, from the West Indies, and my *Mecoliotia halligani* from Funafuti. *Acanthogorgia muricata*, described by Verrill from

* Willey—Quart. Journ. Micro. Sci. xxxix. 1896, p. 220.

Barbadoes, has been rediscovered at Funafuti.* Six medusæ are noted as common to Fiji and the West Indies.† Darwin wrote that "not one single sea-shell is known to be common to the Pacific and to the west coast of America," but the statement is no longer true.

A list of the Polynesian fauna which reappear on the west coast of America would be of value. Materials are at present wanting to construct it, but it is evident that the proportion is small. Their extension eastwards is obstructed partly by the large expanse of water unbroken by islands, and partly by the cold current which flows northwards along the American coast.

No sign of an American immigration can be traced in the Central Pacific. Had the Trans-Pacific Jurassic Continent advocated by such writers as Hutton and Baur any foundation in fact, then, if not terrestrial, at any rate marine forms should now extend eastwards from America along its former site.

* Hiles—Proc. Zool. Soc. 1899, p. 48.

† Agassiz and Mayer—Bull. Mus. Comp. Zool. xxxii. 1899, p. 158.